<u>Heating Things Up Lesson</u>

Developed by: Dr. Kevin Czajkowski & Janet Struble

Purpose
To investigate the different rates of heating and cooling of certain materials on earth in order to understand the heating dynamics that takes place in the Earth's atmosphere.

Overview
Working in small groups, students will explore the energy transfer of different earth materials when they are heated up and cooled down. The students graph the changes in temperatures that occur over a 15-minute period of heating the earth material up and a 15-minute period of the earth material cooling down.

Student Outcomes
Students analyze the data collected from heating and cooling of different earth materials to infer what happens in the Earth's atmosphere.

Science Concepts
Earth and Space Sciences
The atmosphere is composed of different gases and aerosols.
The sun is the major source of energy for changes in the atmosphere.
The sun is the major source of energy for Earth's surface processes.
(Not in the list)
The Sun is the source of energy that heats the Earth including the atmosphere. The Sun heats the Earth's surface. That heat is transferred to the atmosphere from the surface by conduction and convection.

Physical Sciences
Matter exist in different states – solid, liquid and gas.
Heat transfer occurs by radiation, conduction, or convection.
Light /radiation interacts with matter.
The sun is a major source of energy on the Earth's surface.
Energy is transferred in many ways.
Heat moves from warmer objects to cooler objects.
Energy is conserved.

Other
Heat is kinetic energy of molecules and atoms.
Materials heat up and cool down at different rates.
Thermometers measured the kinetic energy of the molecules of the materials. The measurement is in degrees Celsius.

Science Inquiry Abilities
Use of Infrared Thermometer (IRT) or regular thermometers
Design and conduct scientific investigations.
Use appropriate mathematics to analyze data.
Communicate results and explanations.

Time 2 class periods

Level Middle and Secondary

Materials and Tools
5 plastic containers of the same size
Hand-Held Infrared Thermometer (IRT) or 5 thermometers
Sand
Soil
Grass
Water
Gravel or Rocks
A sunny day or 5 desk lamps or clip on shop lights with 100-watt light bulbs
Stopwatch or timer

Preparation
Put equal amounts of each earth material in separate containers.
Prerequisites none

Background
What is heat?
Heat is energy; in fact, it is kinetic energy. Energy, in general, can be classified as potential or kinetic. Potential energy is stored energy that an object possesses due to its position. Kinetic energy is energy of motion.

The kinetic energy of heat is associated with the molecules (atoms) that make up matter. The more kinetic energy the molecules in matter possess, the faster the molecules vibrate, and the hotter the matter will be. So, when you think of heat, think of movement of molecules (atoms).

What happens to this energy in materials?
States of matter are solids, liquids and gases. In a solid material, the molecules are set in place but can rotate and vibrate. The temperature of the solid indicates this rotational and vibrational energy. An example you can tell students is to stay seated in their seats and they cannot move their seats from their spot. Now the students can move their bodies while they are seated (vibrational) and they can turn their seats around (rotational) if it had wheels' underneath it. As this solid absorbs energy, the molecules can gain enough energy to move from their places and can slide pass each other. The solid now changes to a liquid. In our classroom analogy, students possess enough energy to form lines to move, but they need to stay within the walls of the classroom. The substance absorbs more and more energy. It possesses so much energy that molecules move in all directions, vibrate faster, and rotate faster. Now relating this back to students, the students are on the playground or gym. They can run in any direction, spin around, and wave their arms and hands. If the student happens to bump into another student or wall, the student just bounces off and changes direction.

In what ways does energy move?

Energy can move from one place to another by radiation, conduction, or convection.
Radiation

The Sun is our source of radiant energy. Inside the Sun, thermonuclear reactions are taking place. The result of these reactions is tons of energy! This energy travels through space in all directions in the form of electromagnetic radiation. The electromagnetic radiation constitutes the electromagnetic spectrum. This electromagnetic spectrum is comprised of waves of different wavelengths and energy levels. The visible spectrum of light is just one narrow band in this. The electromagnetic spectrum spans from radio waves having the longest wavelength and the least amount of energy to gamma rays having the shortest wavelength and the most amount of energy.

Radiant energy travels through space. When it reaches a molecule, the energy can do one of two things: a) the energy can be reflected in a different direction or b) the energy can be absorbed by a molecule. If the atom absorbed the energy, this increases the kinetic energy of the atom that, in turn, increases the heat of the matter.

As stated earlier, the Sun sends out all types of waves, but the most important ones are the visible light and infrared radiation. Most of the incoming radiation reaches the surface. Air in the Earth's atmosphere is 98% composed of nitrogen (78%) and oxygen (20%) molecules. These molecules do not absorb the radiation. There are parts of the atmosphere such as the ozone layer in which the atmosphere is directly heated by the Sun. This will not be covered by this lesson. The lower part of the atmosphere (Troposphere) is also heated through conduction and convection of energy from the Earth's surface.

All matter radiates energy. Visible light is absorbed by the Earth's surface. When the land and water on Earth absorb this energy, the Earth's surface warms. The Earth's surface radiates energy towards the atmosphere in a form of infrared waves. Some of this energy is radiated to space. This energy coming from the warm surfaces is how the Earth keeps from warming up too much. Molecules in the air (water vapor and carbon dioxide) absorb the infrared radiation; this increases their kinetic energy. This means that the lower part of the atmosphere is heated more from below than from above (radiation from Sun). The primary source of energy that sustains life and drives the weather on Earth is radiant energy from the Sun. If the Earth's radiant energy is in balance, the amount of radiant energy that reaches the Earth's surface is equal to the amount of energy radiated back to space; therefore, the net kinetic energy (temperature) of Earth's surface and atmosphere stays almost constant.

Conduction
Conduction is energy transfer by contact. When one molecule collides with another molecule, energy is transferred from the more energized molecule to the less energized molecule. As this continues to happen, the kinetic energy of the substance is increased, it gets hotter. The opposite also happens; a molecule can lose energy.

A small portion of the heating of Earth's atmosphere occurs as a result of energy transferred to air molecules that have made contact with heated surfaces such as land and water. There is a small portion due to transfer of heat from organisms. Also, the Earth's atmosphere can cool as a result of energy transferred by contact between air molecules and cold surfaces.

Convection
Let's continue to look at the heated air in the Earth's atmosphere. When air comes in contact with the heated surface of the Earth, energy is transferred to the air as conduction as mentioned previously. The kinetic energy of the land is transferred to the air molecules; the air molecules have more kinetic energy and move farther apart (gas expands). The increase in volume without an increase in the number of molecules makes air less dense. The lighter air (less dense) begins to rise. As it rises, it travels to higher levels in the atmosphere where the temperature is cooler. The molecules cool and lose their kinetic energy; the gas becomes denser and sinks down to the Earth's surface. When the cool air comes in contact with the Earth's surface, it heats up and the process starts again. This cycle of rising and falling of the air is convection.

Convection can only happen in fluids, meaning liquids and gases. The molecules need to be able to move which cannot happen in a solid. Convection is usually thought of the third way that energy is transferred in the atmosphere. A simple description is energy transportation. The processes by which energy transfers from one molecule to another are radiation and conduction. Convection is analogous to an elevator that carries heated (high energy) molecules up and cooled (lower energy) molecules down.

What is temperature?
Heat is an abstract idea that is sometimes hard to comprehend. Scientists needed a way to observe it, quantify it, and put it in concrete terms. The invention of the thermometer helped scientists to do this. Temperature is the measure of the average level of kinetic energy in a material. When you use a thermometer, the energy of the matter you are using is transferred by conduction to the liquid that is in the thermometer. The liquid in the thermometer expands or contracts and you read a number on the glass tubing. This number is called the temperature.

Teacher Preparation
Heat is a hard concept for students to understand. It is not a substance, but a form of energy. So, what does the temperature tell us about the amount of heat in the substance? Nothing! The thermometer does not measure the amount of heat; it measures the level of kinetic energy. This distinction is hard for students and even adults to understand. The big idea of this activity is that heat is energy; energy has many forms; energy can move from one place to another by radiation, conduction, or convection. One form of energy is the motion of molecules (atoms)—kinetic energy. Thermometers are used to detect this heat-transfer phenomenon; temperature is used to compare the kinetic energy of different substances as heat moves.

Note: The container of grass is missing in this photo.

What To Do and How To Do It

1. Teacher tells the students to think about a hot sunny day at the beach. You are barefooted. What surfaces would you walk on and why? Why are some surfaces cool to your touch? Why are some hot to your touch? From where did the hot surfaces get their energy? [Sun]
2. Tell the students that today they are going to investigate what happens to air and different earth materials when they are exposed to the Sun. Mention some of the materials the students may have told you earlier such as sand, grass, rocks, etc. Try to get the students to mention water, bare soil, and air.
3. Each group will record the temperature change of each earth material. Each container should have about the same amount of material. If it is a sunny day, this activity can be done outside. If not, desk lamps or shop lights can be used to simulate the sun's energy.
4. If you are using thermometers, place them in the earth material.
5. For each earth material, designate a recorder that will record the temperatures and person that will measure the temperature in degrees Celsius.
6. Record the beginning temperature of each material. Start the timer and the timekeeper needs to tell the students when they should measure the temperature with the IRT or read the thermometers. If you are using one IRT, try to have the students take the measurements as close together in time as possible.
7. Students will record the temperature of the earth material in the sun or under the light every 3 minutes for a total of 15 minutes. After 15 minutes, the earth materials are shaded or the lights turned off. Measure the temperature every 3 minutes for the next 15 minutes. The total elapsed time is 30 minutes with 11 temperature measurements.
8. See the example of a data table that students can fill in or have the students create the data table in their science notebooks.
9. Each group shares their data either by writing the numbers on a large chart or on an overhead transparency. Each student records the data on Data Table Sheet or in one's notebook.
10. Now look at the data. Does each material in the container start at the same temperature? [No] How can we compare them to see which one had the most change in temperature?

[Subtract the current temperature from the initial temperature and you will calculate the change in the temperature.] Using this data, you can see the change in the material over time. Emphasize: subtract the temperature from the beginning temperature. This means the first row in Data Table Sheet 2 will be all zeroes. Students fill in Data Table Sheet 2. This can be assigned for homework.

11. The next day the teacher reviews what was done yesterday and brings out the data table sheet 2. As a class, fill in the changes in temperature.
12. One way scientists analyze their data is by graphing the data. In order to look at what is happening with each material, you will graph the data of all materials on one graph. Each material data will be graphed in a different color. Use colored pencils to identify the different materials. The teacher may want to assign the colors, such as blue will represent the water, green the grass, and so on.
13. If needed, review how to do a graph. The x-axis displays the independent variable which is time; the y-axis displays the dependent variable – change in temperature. The students select appropriate and uniform intervals and write them on the graph paper.
14. As students work on graphing the data, the teacher looks over the groups to make sure students are graphing correctly. If the teacher chooses this graphing exercise as an assessment, a rubric is provided at the end of this activity.
15. The following questions can be used for class discussion or as an individual assignment. Questions for discussion:

    - Did all the earth materials heat up at the same rate? Explain the evidence for your answer.
    - Did all the earth materials cool down at the same rate? Explain the evidence for your answer.
    - Which earth material heated up the fastest? How do you know this? Explain why this may have happened.
    - Which earth material cooled down the fastest? How do you know this? Explain why this may have happened.
    - Did each earth material receive the same amount of energy? How do you know?

16. What you should find from this investigation is that water is the slowest to heat up and cool down. All the materials received the same amount of energy. So why do you think that the water increased so little? For water, it takes five times more heat energy to raise the temperature of an equal amount of dry soil or sand one degree. When the same amount of energy is absorbed equally by all of the earth materials, the temperature of the solid earth materials will increase faster and greater than water. In addition, water is a liquid that mixes. The energy for water is mixed throughout its volume while only the very surface of solids is heated.

17. Introduce the concept of radiation in the Earth's atmosphere. The teacher may ask, "The Sun heated up each earth material in the containers. How does this happen? How does the energy from the Sun get from the Sun to the sand? Water? Grass? Soil? Rocks?" The teacher needs to draw out the students' understanding of this first, then provide an explanation that will clear up misconceptions. This information is in the section "Background." The following is a short synopsis.

The energy that comes from the Sun is radiant energy that travels in waves through space. This energy makes up the electromagnetic spectrum. Some waves that you may be familiar with are visible light (which we can see), radio waves (listening to radio station in your car), and microwaves (like your microwave oven that can heat up things). When the energy hits a molecule or atom such as molecules of sand or water, the molecule gains energy. This gain in energy makes the molecule vibrate or move faster. We say the molecule absorbed the energy. This molecular movement is what we call heat. The more the molecules move, the more heat is produced.

Data Table Sheet 1:

Time	Bare Soil	Grass	Gravel or Rocks	Sand	Water
Beginning					
3 minutes					
6 minutes					
9 minutes					
12 minutes					
15 minutes					
18 minutes					
21 minutes					
24 minutes					
27 minutes					
30 minutes					

Data Table Sheet 2:

Time	Bare Soil	Grass	Gravel or Rocks	Sand	Water
Beginning					
3 minutes					
6 minutes					
9minutes					
12 minutes					
15 minutes					
18 minutes					
21 minutes					
24 minutes					
27 minutes					
30 minutes					

Rubric for graphing:

Score	Rationale
4	• The graph is correctly labeled with the title, axes, units, and key for the colored lines. • The students used appropriate and uniform intervals. • The graph is accurately and neatly done.
3	• The graph is missing one or more of the following labels: title, axes, units, or key for the colored lines. • The students used appropriate and uniform intervals. • The graph is accurately and neatly done.
2	• The graph is missing on or more of the following labels: title, axes, units, or key for the colored lines. • The graph is accurately and neatly done but the student did not use uniform intervals.
1	• The graph is not labeled. • The student did not use uniform intervals. • The graph is not accurately and neatly done.